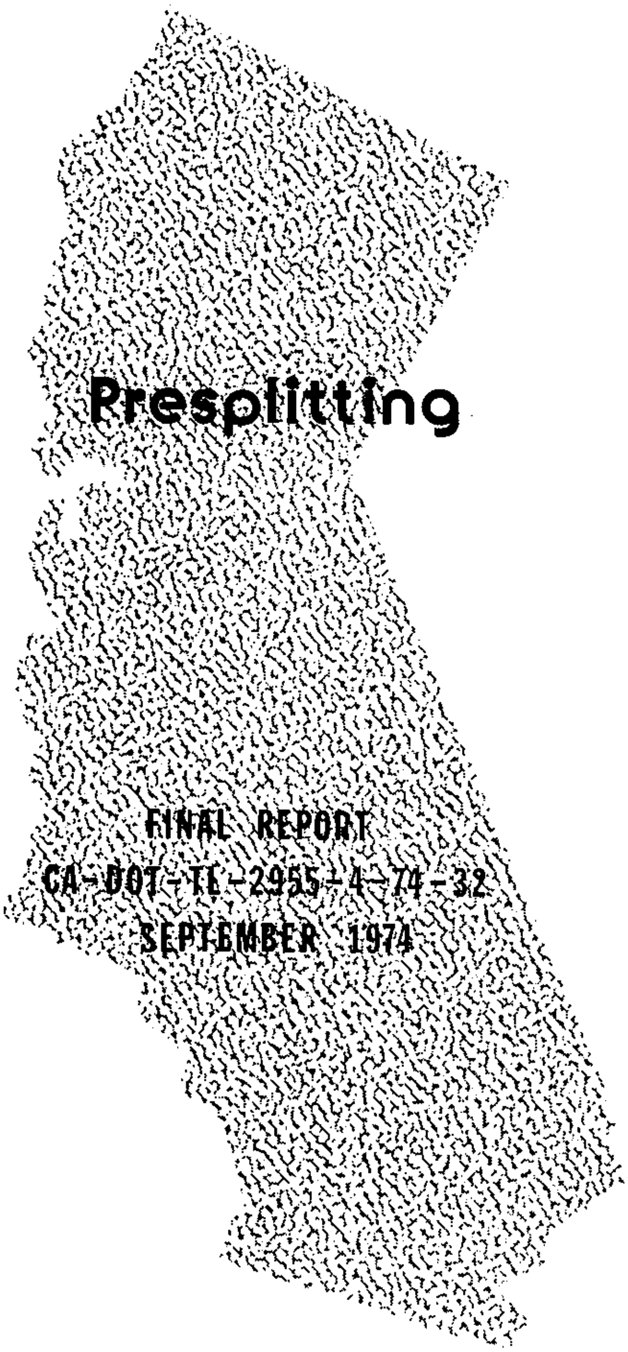
PRESPLITTING

FINAL REPORT # FHWA/CA/TL-74/32

CALTRANS STUDY # F-8-7

74-32

CALIFORNIA DIVISION OF HIGHWAYS
TRANSPORTATION LABORATORY
RESEARCH REPORT



Presplitting

FINAL REPORT
CA-DOT-TL-2955-4-74-32
SEPTEMBER 1974

Prepared in Cooperation with the U.S. Department of Transportation,
Federal Highway Administration

Caltrans
CALIFORNIA DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Presplitting, A Final Report		5. REPORT DATE September 1974 6. PERFORMING ORGANIZATION CODE 19203-762503-632955
7. AUTHOR(S) McCauley, Marvin L., Hoover, Thomas P. and Forsyth, Raymond A.		8. PERFORMING ORGANIZATION REPORT NO. CA-DOT-TL-2955-4-74-32
9. PERFORMING ORGANIZATION NAME AND ADDRESS Transportation Laboratory 5900 Folsom Boulevard Sacramento, California 95819		10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. F-8-7
12. SPONSORING AGENCY NAME AND ADDRESS California Department of Transportation Sacramento, California 95807		13. TYPE OF REPORT & PERIOD COVERED Final 14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This report is a synthesis of three interim reports on Presplitting of high cut slopes. Observations are presented on the economics, construction, and maintenance aspects of presplitting in addition to the general conclusions and recommendations of the authors, and the specifications developed as a result of the study.

17. KEY WORDS Construction methods, evaluation, cuts, slopes, rock presplitting, specifications		18. DISTRIBUTION STATEMENT Unlimited	
19. SECURITY CLASSIF. (OF THIS REPORT) Unclassified	20. SECURITY CLASSIF. (OF THIS PAGE) Unclassified	21. NO. OF PAGES 32	22. PRICE

HMRT - 1242 (ORIG. 9/72)

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
TRANSPORTATION LABORATORY

September 1974

FHWA No. F-8-7
TL No. 632955

Mr. R. J. Datel
State Highway Engineer

Dear Sir:

I have reviewed and now submit for your information this final research report titled:

PRESPLITTING

A Final Report

Study made by . . . . Foundation Section

Under the Supervision of . . . . R. A. Forsyth

Principal Investigator. . . . . M. L. McCauley

Co-Investigator . . . . T. P. Hoover

Report Prepared by. . . . . T. P. Hoover

Very truly yours,

JOHN L. BEATON
Chief Engineer, Transporation Laboratory

Attachment

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ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the Construction and Maintenance personnel of the California Division of Highways in Districts 02, 06 and 07.

Special thanks are extended to Messrs. A. B. Horton, R. R. McDonell, H. Mitchell, E. Poch, M. Silva and A. VanRhyn for their observations, comments and cooperation. Special thanks are also extended to R. Mortensen for the excellent photographic coverage provided for this project.

This work is being done in cooperation with the U. S. Department of Transportation, Federal Highway Administration (Federal Program No. HPR1(2), F-8-7).

The contents of this report reflect the views of the Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

INTRODUCTION

Presplitting is a method of precise excavation utilizing slope drilling within the plane of intended slope with detonation of the slope holes prior to production blasting. The techniques and problems encountered by the California Department of Transportation have been previously discussed in three interim reports. These reports dealt with three materials, metamorphic, granitic, and sedimentary rocks in three different areas. They were constructed by three different contractors with different inspectors on each project. The first report "Presplitting Interim Report" November 1970, by Travis Smith, et al., discusses metamorphic rock; the second "Presplitting Interim Report 2" May 1972, by Travis Smith, et al., covers granitic rock and the third "Presplitting Interim Report 3" March 1973 by Raymond A. Forsyth, et al., deals with sedimentary rocks.

This report, the fourth and final of the series, is a synthesis of the conclusions developed in the previous reports, maintenance observations, construction observations and observations from non-research presplitting, as well as other relevant information.

CONCLUSIONS AND RECOMMENDATIONS

The Division's use of presplitting up to this time has produced steeper cut slopes with a smoother appearance, the need for less scaling and what appears to be, after three to five years of weathering, more stable slopes. (See Plates 1-6)

To realize the maximum benefit from the presplitting technique, it is necessary to use the proper combination of bore hole diameter, spacing and length of bore holes, and proper type, size, and spacing of explosives. The required combination of these variables must be determined by experimentation in each cut. Using the specifications as a guide is helpful, but previous experience in presplitting results in less wasted effort and lower costs.

To prevent a recurrence of the problems encountered on one project, it is recommended that presplitting not be used in borderline rock unless the necessary experimentation has been successfully completed. The experimentation provision is included in the specifications and should be rigidly enforced.

Also, no recommendation for presplitting should be extrapolated without a detailed field review by an engineering geologist familiar with the presplitting technique.

The slight increase in direct construction costs using the presplitting technique are almost balanced by reduced excavation quantities. Reduced right-of-way costs, anticipated decreases in maintenance cost, and improved safety are additional benefits.

It is recommended that presplitting, with the specifications included in this report, be considered for all blasting excavation with slopes steeper than 1:1.

IMPLEMENTATION

The knowledge and experience gained by the Transportation Laboratory on this project is being used as a basis for recommending presplitting on other projects.

The Transportation Laboratory has conducted meetings to inform Headquarters and District personnel of the current state of knowledge concerning presplitting. Additional meetings of this type are planned.

The specifications developed as a result of this project have been issued as a standard special provision by the California Department of Transportation.

METHOD

The major factors controlling effective presplitting are:

1. Parallel alignment of holes
2. Horizontal spacing of holes
3. Type of explosive
4. Size of explosive charge
5. Placement pattern of explosive charge
6. Diameter of drill holes

The interrelationships of these variables have not yet been completely defined. Thus, experience and experimentation dictate their values. Experience has shown that the varying of horizontal hole spacing, explosive pattern and charge size can yield acceptable presplitting. The Department of Transportation specifications set logical limits as well as starting points for these variables. These specifications call for 2-1/2" - 3" holes because compatible equipment and explosives are readily available. Hole alignment specifications include tolerances of 12" perpendicular to the slope and 1/3 of the planned horizontal spacing within the slope.

A minimum of experimentation with these limits when used with explosives, hole spacings and explosive patterns selected by the contractor usually yields acceptable presplitting. These requirements are covered in the specification section.

Proper alignment and the selection of explosive charge sizes and patterns that are compatible with the rock to be excavated are essential to good presplitting. If poor alignment and overblasting are prevented, a minimum of experimentation with hole spacing and loading can yield good presplitting.

The occurrence of fractures which follow the trace of presplit holes was investigated as a special study within this project. The hypotheses under study was that the fracture which is perpendicular to the slope and extends back into the slope was a result of explosive strength being excessive for the rock strength. This phenomenon appeared to be associated with column explosives. The results of this study are presented in Appendix B.

CONSTRUCTION OBSERVATIONS

It is desirable that the contractor and Resident Engineer have preconstruction knowledge of presplitting. If either is inexperienced in this area, he should become familiar with presplitting principles, methods, and specifications.

Presplitting apparently reduces the scaling time for slopes by 50 to 80%. These figures are based on Resident Engineer's estimates. Not only is there less material to scale but the steeper slope facilitates scaling activities.

Minor slides in overburden have occurred. The probable causes have been poor quality presplitting, and/or improper overburden removal. Poor presplitting can be caused by: overshooting, the use of too large a quantity of explosive for the material to be excavated; improper alignment of drill holes due to inadequate equipment, or insufficient care in preparing a pad to drill from, or insufficient care in aligning the drill within the plane of planned slope prior to drilling. Overbreak, breakage from excessive production blast explosive charges, may also result in poor presplitting.

Drilling is of prime importance for good presplitting. In order to obtain acceptable presplit holes, equipment capable of drilling without excessive deviation from the specified alignment must be used. Care must be exercised when setting up this equipment. (See Plates 7-9)

The requirement of stemming should be determined during the testing phase of excavation. In many cases it is an unneeded expense.

The testing phase is of primary importance. If good presplitting is not being achieved short sections, up to 100 ft., should be excavated until a method of achieving good presplitting is determined. The method determined by such testing should be used to complete the presplitting. These test sections can be varied by adjusting the hole spacing, charge size, charge loading pattern, the drilling alignment or the introduction of auxiliary holes. (Auxiliary holes are identical to presplit holes but are not loaded with explosives.)

Inadequate overburden removal may occur at the cut flanks or top of cut. Cuts in overburden should not be as steep as in hard rock. Overburden not removed from cut flanks may result in small slides or slipouts. (See Plates 10-12.)

ECONOMICS

The cost of presplitting includes the amount paid to the contractor for drilling, loading and shooting the presplit holes and the increased engineering cost due to the need for additional inspection on the project. This cost is counter-balanced by reduced earthwork quantities resulting from steeper stable slopes, reduced right of way, a more favorable excavation bid, reduction of hazards to the travelling public and some reduction in maintenance costs.

As stated in the interim reports it has been our experience that the reduced excavation quantities offset 80 to 90% of the extra costs associated with presplitting.

We have not investigated right of way costs and therefore cannot estimate the monetary savings. Our experience has, however, shown substantial land requirement savings when long, high cuts are presplit. More then one-half acre of right of way would be deleted if a 25% steeper, 3/4:1 rather than 1:1, slope were used on a 1000 ft. long, 100 ft. high, cut.

Resident engineers have indicated that required scaling time is substantially less. This savings should be reflected in lower excavation bid prices.

An aesthetic factor of importance results from preslitting a smaller exposed cut face. A reduction in cut areas also lessens environmental impact. Another factor of importance is cut height. In areas where natural slopes are relatively steep, the flatter design required by non-presplit slopes would be substantially higher than the presplit slope design.

The smooth presplit slope, however, may be objectionable. The drill hole traces are also an unnatural phenomenon which is readily visible from the travel way.

MAINTENANCE OBSERVATIONS

The prevention of rockfall by constructing steeper more stable slopes decreases the hazard to the traveling public. Rockfall in presplit cuts is less frequent and of smaller size than it is in cuts constructed by conventional blasting methods. This is based on direct observation and information provided by maintenance personnel associated with the respective locations.

The maintenance costs associated with our presplitting research cut slopes have been minimal where the presplitting was done correctly. The Maintenance Department has not had to clean the shoulders of the road for the projects described in interim reports 1 and 2. This is true for both the presplit slopes and the control sections. There is, however, a larger quantity of accumulated rockfall on the shoulders of the road under non-presplit slopes than under those slopes which were presplit.

SPECIFICATIONS

A method specification is one in which the specification delineates the method by which the contruction is to be accomplished. An end result specification delineates only the final result desired. The best presplitting for the least cost appears to be best accomplished by a combination of these two types of specifications. An end result specification is used by one organization which was interviewed. That organization has had at least one occasion upon which the end results were unacceptable and therefore were not paid for. They did, however, have to underwrite the cost of corrective measures for the slope which was unstable and unsafe as constructed. The corrective measures taken included slope flattening which resulted in an increase in right of way as well as related construction costs. This resulted in a larger disturbed area thus increasing the environmental impact. Our current recommendations for presplitting specifications are in Appendix A. These are used as Standard Special Provisions and are distributed to the State Transportation Districts.

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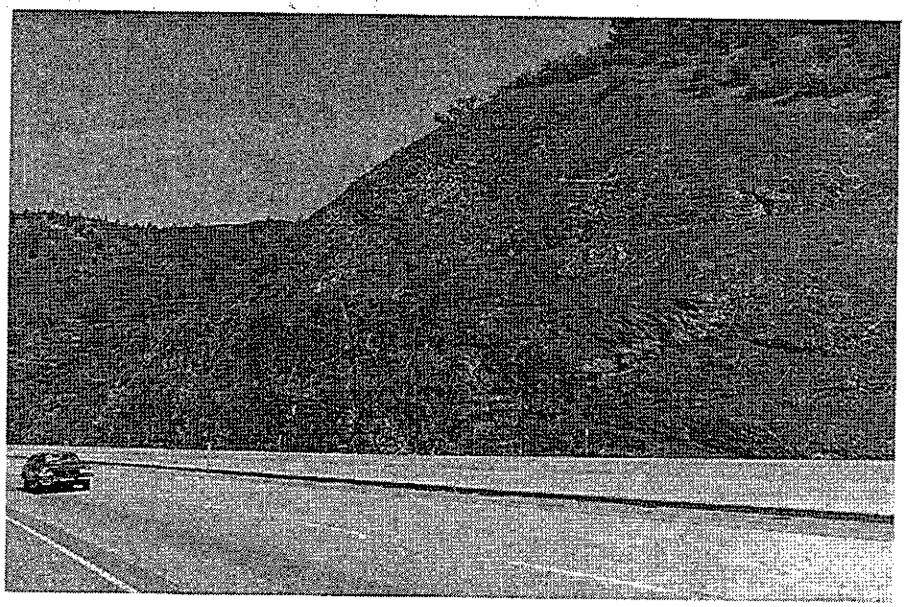
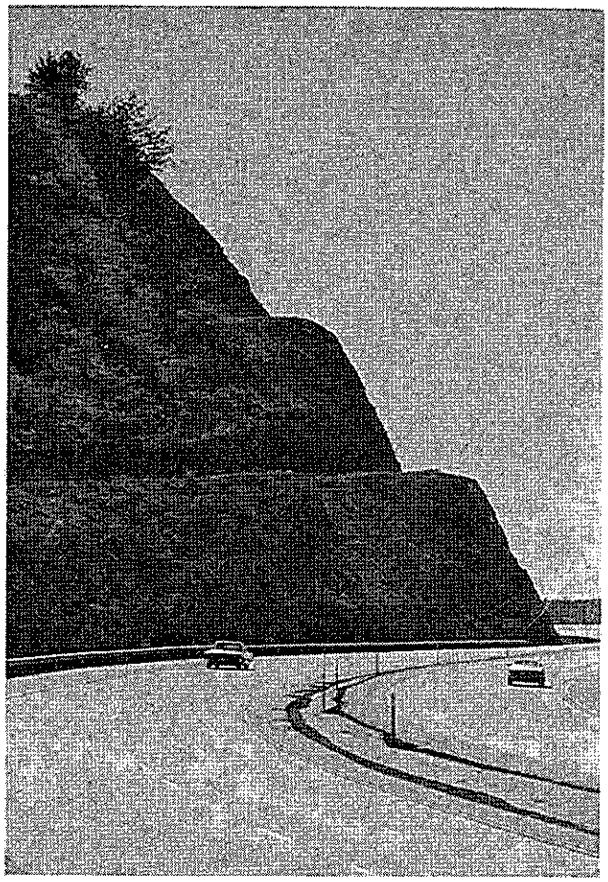


Plate 1 4/16/74 Presplitting in Metamorphic Rock

Plate 2
4/16/74
Steep Slopes
Constructed by
Presplitting in
Metamorphic Rock



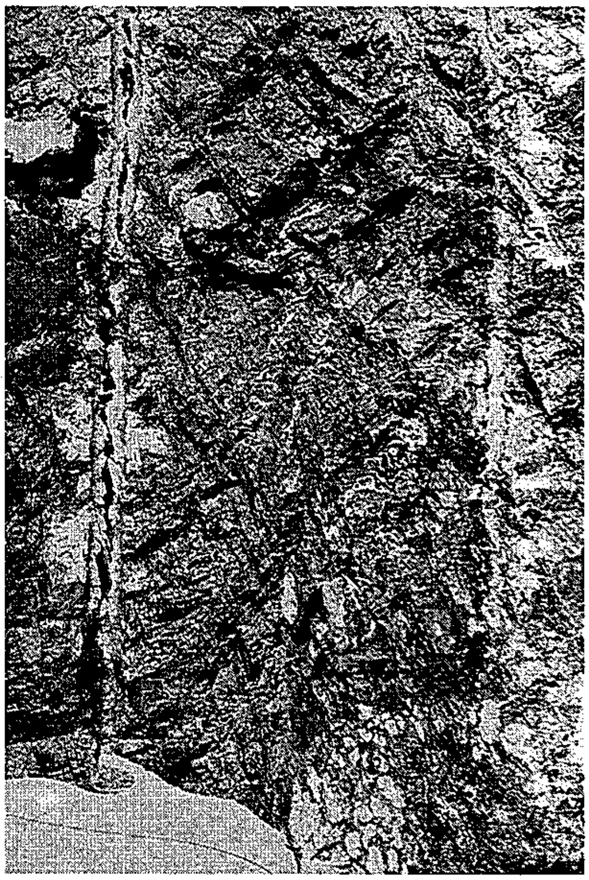


Plate 3 - Fracturing of presplit borings in metamorphic rock

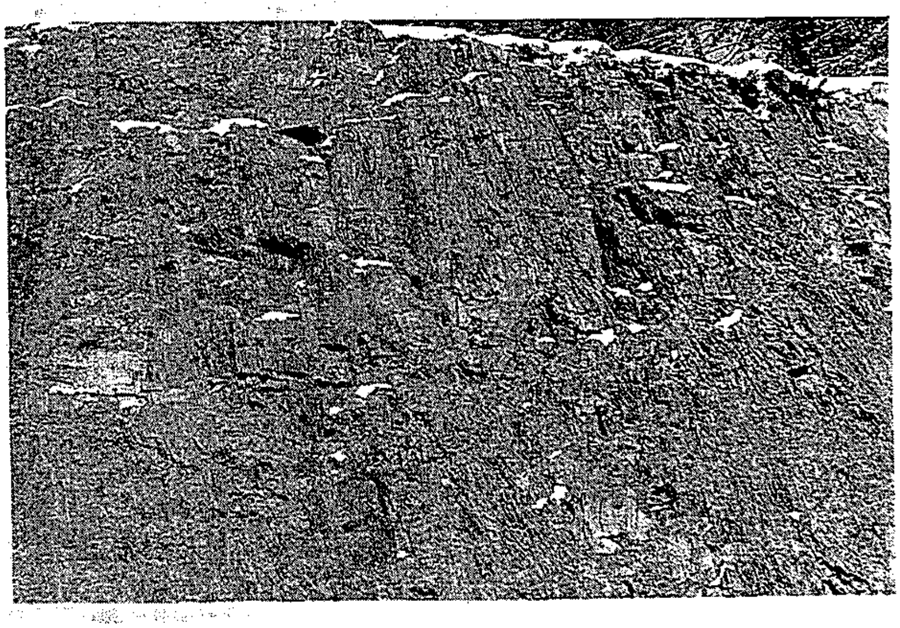


Plate 4 - Appearance of cut slope

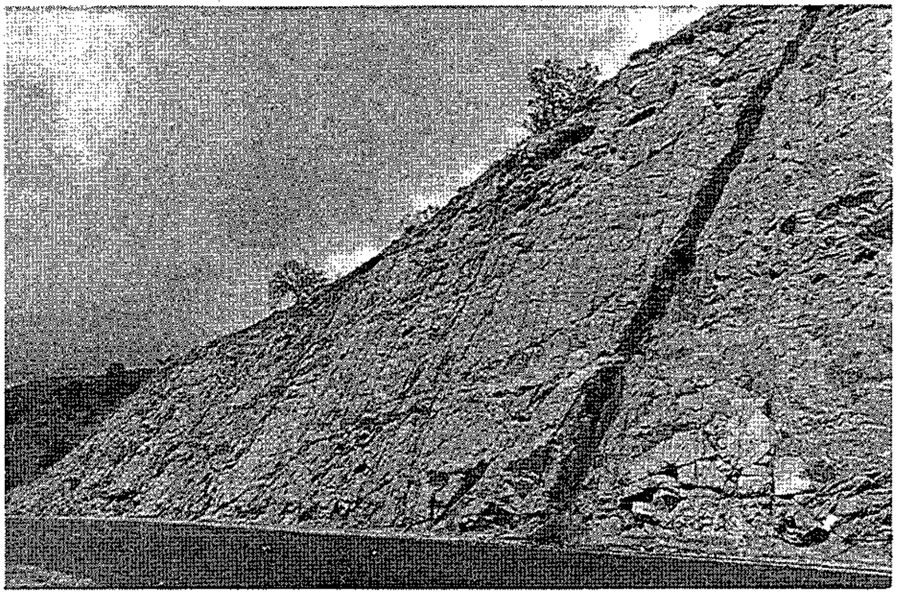


Plate 5 4/9/74 Presplitting in Granitic Rock

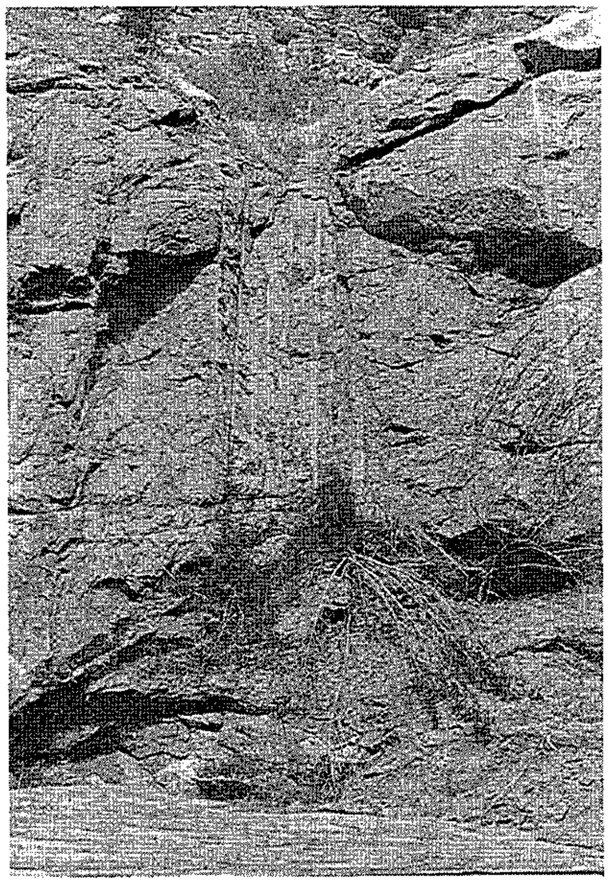


Plate 6
4/9/74
A Downdrain
Constructed by
Presplitting Methods

Plate 7 4/9/74 Non-parallell Drilling of Presplitting Holes

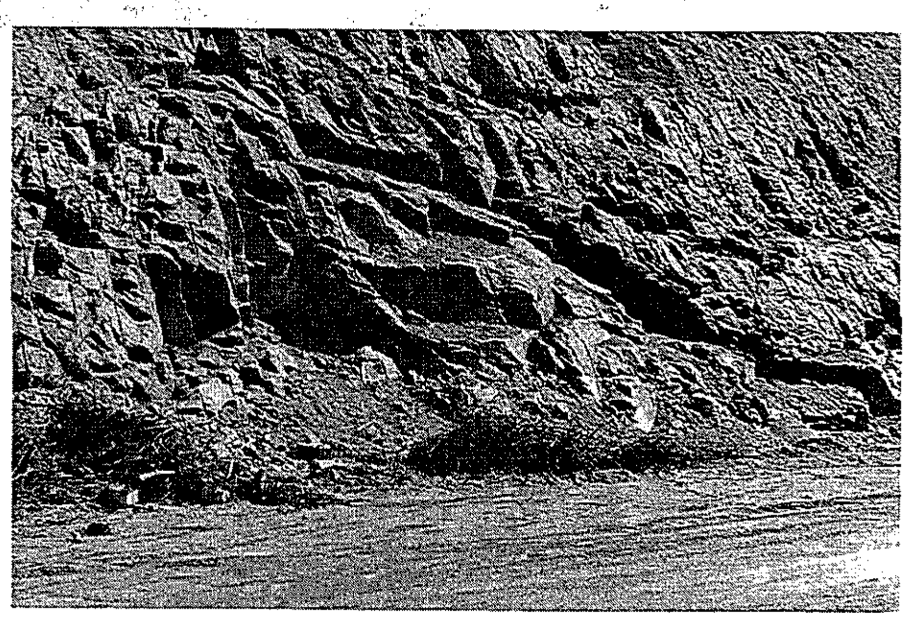


Plate 8 4/9/74 Non-planar Disturbed Slope Resulting from Poor Drill Hole Alignment

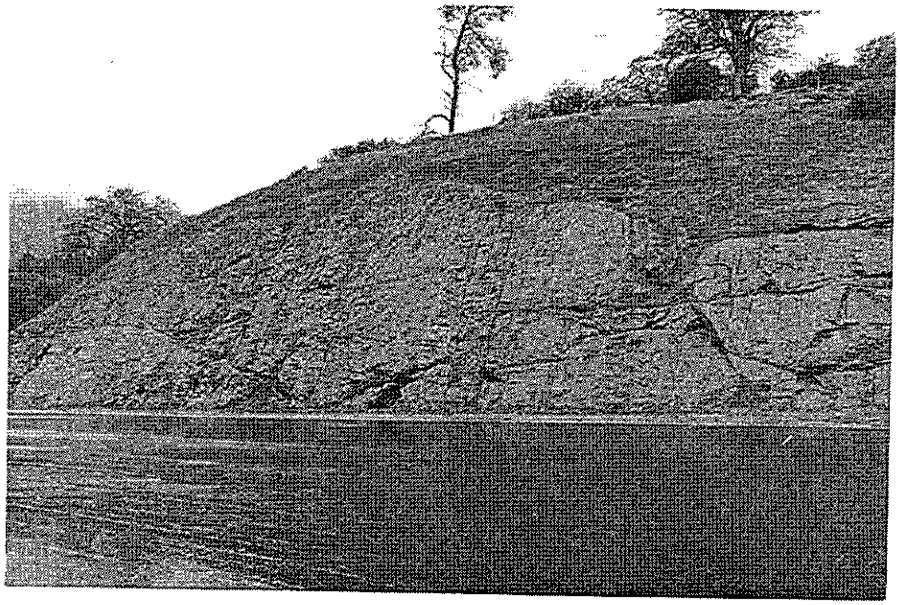


Plate 9   4/9/74   Smooth Stable Slope Resulting from Parallel Planar Drilling

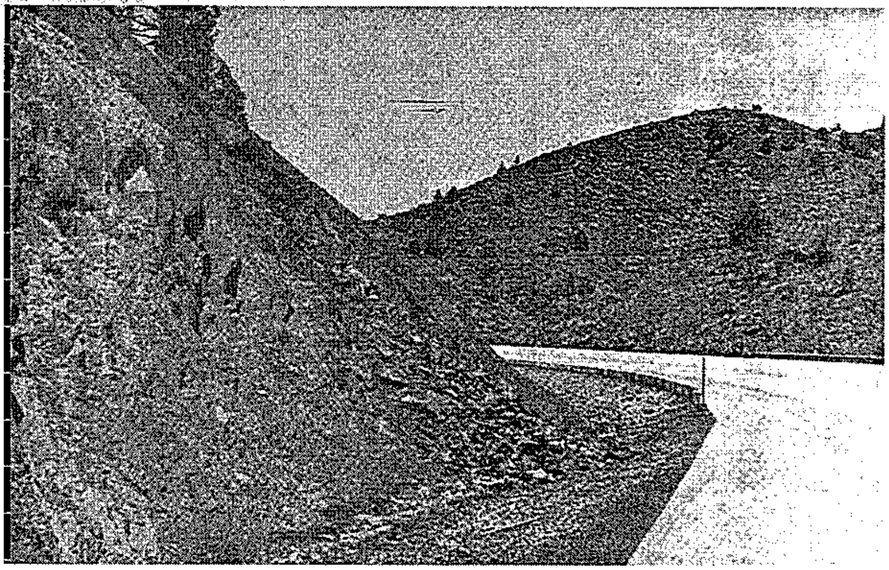
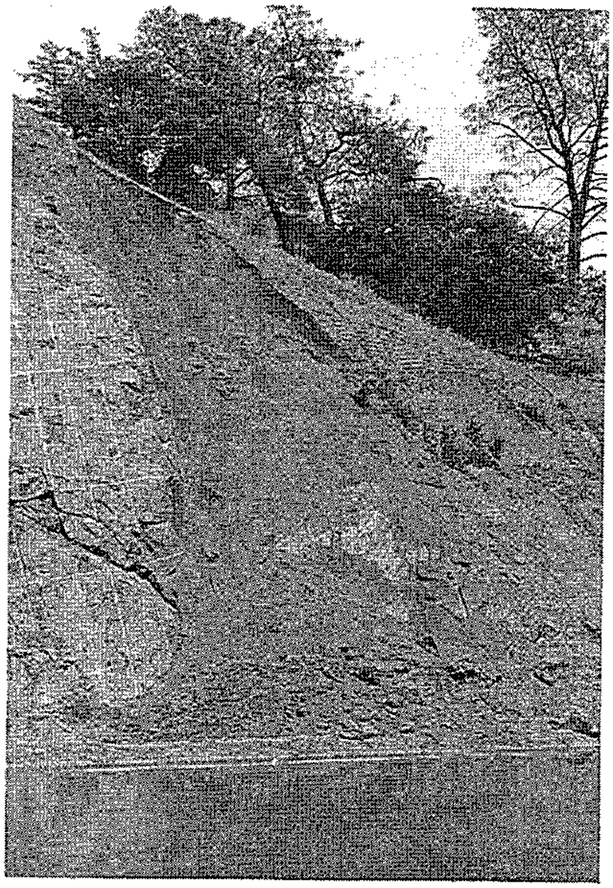


Plate 10 4/16/74 An Overburden Failure in the Flank of a Presplit Cut in Metamorphic Rock

Plate 11
4/9/74
An Overburden Failure
in the Flank of a
Presplit Cut in
Granitic Rock



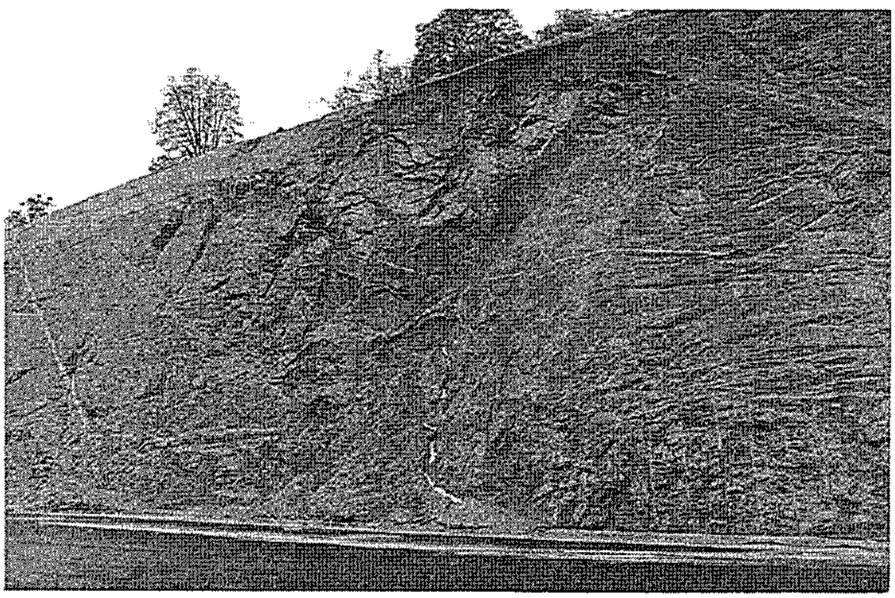


Plate 12 4/9/74 An Overburden Failure Above the Presplitting in Granitic Rock

APPENDIX A

RECOMMENDED SPECIFICATIONS FOR PRESPLITTING

ROCK CUT SLOPES

Presplitting rock cut slopes shall be performed at the locations described herein in accordance with the excavation provisions in Section 19 "Earthwork" of the Standard Specifications and these special provisions.

Presplitting is defined as the establishment of a free surface or shear plane in rock along the specified cut slope by the controlled usage of explosives and blasting accessories in appropriately aligned and spaced drill holes.

The presplitting technique, as covered herein, shall be used for forming rock cut slopes when designated in the plans.

The contractor shall first completely remove all overburden soil and weathered rock along the top of the cut for a distance of at least 50 feet beyond the drilling limits or to the end of cut, prior to drilling the presplitting holes. Particular care and attention shall be directed to the beginning and end of cuts to insure complete removal of all overburden soil and weathered rock and to expose fresh rock to an elevation equal to the bottom of the adjacent lift of presplitting holes being drilled.

Slope holes for presplitting shall be drilled along the line of the planned slope within the tolerances herein set forth. These tolerances also apply to auxiliary holes which are identical to presplitting holes except they are not loaded with explosives. The drill holes shall not be less than 2-1/2 inches and not more than 3 inches in diameter. The Contractor shall control his drilling operations by the use of proper equipment and technique to insure that no hole shall deviate from the plane of the planned slope by more than 12 inches nor shall any holes in the plane of the slope be within one-third of the planned horizontal spacing of any other hole.

The length of presplit holes for any individual lift shall not exceed 30 feet unless the Contractor can demonstrate to the Engineer that he can stay within the above tolerances and produce a uniform slope, then the length of holes may be increased to a maximum of 60 feet upon written approval of the Engineer.

The spacing of presplit holes shall not exceed 36 inches on centers and shall be adjusted to result in a uniform shear face between holes.

The Contractor shall place the adjacent line of production holes inside the presplit lines in such a manner as to avoid damage to the presplit face.

The Contractor may be required to drill the first line of production holes parallel to the slope line at the top of the cut and at each bench level thereafter if necessary to reduce shatter and overbreak of the presplit surface.

Any blasting technique, which results in damage to the presplit surface, shall be immediately discontinued.

No portions of production holes shall be drilled within 8 feet of a presplit plane except as approved by the Engineer. The bottom of the production holes shall not be lower than the bottom of the presplit holes.

A maximum offset of 24 inches will be permitted for a construction working bench at the bottom of each lift for use in drilling the next lower presplitting pattern.

The Contractor shall adjust his drilling operations to compensate for drift of previous levels and for the offset at the start of new levels to maintain the specified slope plane.

If at any time the methods of drilling and blasting do not produce the desired results of a uniform slope and shear face without overbreak, all within the tolerances specified, the Contractor shall be required to drill, blast and excavate short sections, up to 100 feet, until a technique is arrived at that will produce the desired results.

The maximum diameter of explosives used in presplit holes shall not be greater than 1/2 the diameter of the presplit hole.

Only standard cartridge explosives prepared and packaged by explosive manufacturing firms will be permitted for use in presplit holes. These may consist of fractional portions of standard cartridges to be affixed to the detonating cord in the field or solid column explosives joined and affixed to the detonating cord in the field.

If fractional portions of standard explosive cartridges are used, the cartridges shall be firmly affixed to a length of detonating cord equal to the depth of the drill hole so that the cartridges will not slip down the detonating cord nor cock across the hole and bridge the flow of stemming material. Spacing of cartridges shall not exceed 30 inches and shall be adjusted to give the desired results.

If a solid column type of explosive is used, the column shall be assembled and affixed to the detonating cord in accordance with the explosive manufacturer's instructions, a copy of which shall be furnished to the Engineer.

The bottom charge of a presplit hole may be larger than the line charges but shall not be large enough to cause overbreak. The top charge of the presplitting hole shall be placed far enough below the collar to avoid overbreaking the surface.

Before placing the charge the Contractor shall determine that the hole is free of obstructions for its entire depth. All necessary precautions shall be exercised so that the placing of the charge will not cause caving of material from the walls of the hole.

Stemming may be required by the Engineer whenever necessary to achieve a satisfactory presplit face. Stemming materials shall be dry free-running material all of which passes a 3/8-inch sieve and 90 percent of which is retained on a #8 sieve. Stemmed presplit holes shall be completely filled to the collar.

All charges in each presplitting pattern shall be detonated simultaneously.

The tolerance requirements of Section 19-2.05 "Slopes" of the Standard Specifications shall not apply to presplit surfaces of cut slopes where presplitting is specified. The presplit face shall not deviate more than one foot from the plane passing through adjacent drill holes, except where the character of the rock is such that in the opinion of the Engineer, irregularities are unavoidable. When completed the average plane of the slopes shall conform to the slopes indicated on the plans and no point on the completed slopes shall vary from the designated slopes by more than one foot. These tolerances shall be measured perpendicular to the plane of the slope. In no case shall any portion of the slope encroach on the roadbed.

As long as equally satisfactory presplit slopes are obtained, the Contractor may either presplit the slope face prior to drilling for production blasting or may presplit the slope face and production blast at the same time, provided that the presplitting drill holes are fired with zero delay and the production holes are delayed starting at the row of holes farthest from the slope and progressing in steps to the row of holes nearest the presplit line, which row shall be delayed at least 50 milliseconds. In either case the presplitting holes shall extend either to the end of the cut or for a distance of not less than 50 feet beyond the limits of the production holes to be detonated.

Those holes that fail to meet the alignment controls specified herein will not be accepted for full payment and holes that are drilled where the finish slope does not meet the slope tolerances specified herein will not be accepted for payment. Only those holes that qualify as to alignment and the slope finish and which show a hole trace for approximately one-half of the drilled length will be accepted and measured for full payment purposes. Those holes which produce an acceptable slope and the plane of the slope shall be paid for at a rate of 75% of bid price. Auxiliary holes shall be compensated for as extra work and paid for at a rate of 75% of the bid price for presplitting holes. No compensation will be allowed for unacceptable presplit work. Evaluation of presplit holes to determine if they qualify for payment will be made after excavation but before any slope trimming or cleanup work.

Measurement of presplitting hole length for payment of acceptable holes shall be by theoretical slope length as computer from elevations taken before detonating each lift, to be presplit, and a plane 3 feet below finish grade. No payment shall be made for drilling more than 3 feet below finish grade unless directed by the Engineer.

The contract price paid per linear foot for drilling holes (presplitting) shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals, and for doing all the work involved in drilling, loading, stemming and detonating, as specified in these special provisions and as directed by the Engineer.

APPENDIX B

December 19, 1972
Lab Auth 632955

MEMO TO: Files

FROM: R. Mearns

SUBJECT: Presplitting Drill Hole Fracture

The recurring appearance of fractures which follow the trace of presplit drill holes and which extend an unknown distance into the hill are the object of some concern. Plates 1 and 2 show examples of this feature. The reason for the concern is that in order for the fracture to develop some disturbance of the rock in the cut face must take place. Since the reason for presplitting is to prevent this disturbance, it seems necessary to determine the cause of the fracture and, if possible, to prevent it.

These fractures were noticed only on those projects where the continuous column type of explosives were used. It was also noticed that in fresh massive rock they did not occur. Fractures also appeared more frequently and/or were more stongly developed if the presplit holes had been stemmed. All of these observations suggest that the amount of explosive energy may be the most significant cause of the fracture.

The fracturing problem described above had been observed by Mr. Art Nelson, Resident Engineer, on a project 03-Sie-49 PM 10.2/13.2 (see Plate 3). The material in this area is a highly fractured and foliated metamorphic rock which is also faulted and moderately to slightly weathered. The appearance of this material is shown in Plate 4. Because this rock had just enough integrity to require blasting, it appeared to be ideal for experimenting.

Discussions between Mr. Tom Hoover of this department and Mr. Nelson eventually lead to the test described in this memo. The Contractor, Hughes and Ladd, cooperated fully and contributed much to the successful completion of this experiment.

The experiment was designed to yield data on the relationship between the amount of explosive energy and the development of the fracture. Three different explosives (see Plate 5) with different amounts of explosive energy were used and an experimental loading technique (see Plate 6) was also tried with one of these explosives. Table 1 contains data on the explosives. Trimtex was the explosive being used by the contractor to complete the project. It is made by DuPont specifically for presplitting.

Each of the explosives are provided with couplers to permit joining the cartridges together. Primacord was affixed to the column as it was joined and placed in the boring. Electric blasting caps manufactured by DuPont were used to detonate the charges. No stemming was used on this project or in this experiment.

A total of thirty borings were included. A random loading pattern was used to eliminate the influence of systematic variation of rock quality. It should be emphasized that there was more concern over eliminating the fracture than in generating a perfect presplit face. The experiment was designed accordingly. Earlier experience with presplitting on the project had indicated that it could be satisfactorily trimmed with a slope board if poor presplitting should occur.

Table 2 lists the borings and the type of loading. The purpose of the spirally wrapped Trimtex was to prevent the main mass of the explosive from resting against the back of the drill hole. It was thought that the resulting air cushion might absorb some explosive energy and result in unfractured drill holes. An attempt was made to use rope for the wrapping but the diameter of the charge was too great and loading the holes could not be accomplished. The Karvite because of the small diameter and weak packaging was found to be difficult to load.

The drill holes themselves were 2-]/2 inches in diameter, were located on 2-foot centers, were 24 feet long and had a slope angle of 1/4:1. The contractor's personnel performed the loading according to the manufacturer's recommendation. A 16 inch x 2 inch stick of 50% dynamite was placed in the bottom of each boring to assure fracture at the bottom. The test holes were detonated simultaneously and at the same time as the regular presplitting holes through the rest of the cut.

The contractor excavated the test area carefully to retain as many hole traces as possible. These hole traces were photgraphed and visually inspected before any scaling of the slope was performed. The results of this inspection are included in Table 3. The appearance of the finished slope is shown in Plate 7. Plates 8, 9, 10 and 11 show the appearance of typical drill hole traces for each different type of loading.

Based on observations of this experiment it appears that excess explosive energy is the cause of the fracture. It also appears that a separation between the charge and the back wall or a 30 to 35% decrease in the amount of explosive will yield satisfactory presplits and reduce the amount of undesirable fracturing.

The Karvite is probably too small a charge to warrant further study because of its failure to split even the borderline material on this project. However, further study should be made of lighter charges and spacers to determine the conditions under which they can be used to alleviate the fracturing. If a suitable test site becomes available, further testing will be performed.

R. Mearns
Associate Engineering Geologist

RM:ml

TABLE I

Explosives

Explosive Name	Manufacturer	Cartridge Size in Inches	Lbs/lineal foot Explosives*
Trimtex	DuPont	7/8 x 24	.175
Kleen-Kut F	Atlas	1-1/8 x 36	.114
Karvite	Hercules	5/8 x 24	.086

*Expressed in equivalent pounds of TNT to permit comparison.

TABLE II

Boring Loading

West East
BBCABAACCACCCDDABABABDAAADDADA

A. - Trimtex
B. - Kleen-Kut F
C. - Karvite
D. - Trimtex with spiral primacord wrap.

TABLE III

Tabulation of Results

Explosive Type	% of Holes Showing Trace	% of Holes Showing Crack	% of Holes Poor Split
Trimtex	50	30	0
Kleen-Kut F	50	16	0
Karvite	20	0	60
Trimtex with Spiraled Primacord	80	20	20

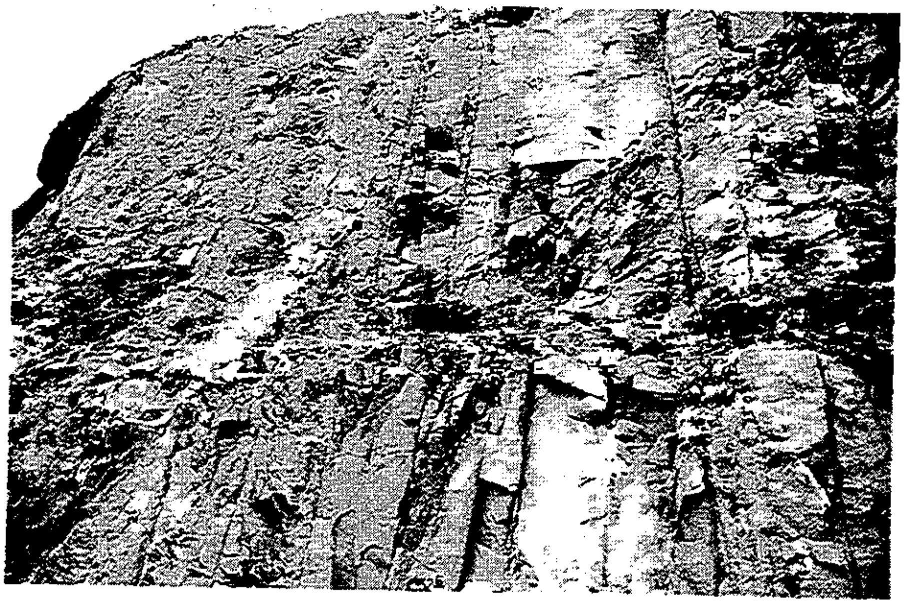


Plate 1 - Fracturing of presplit borings in sandstone

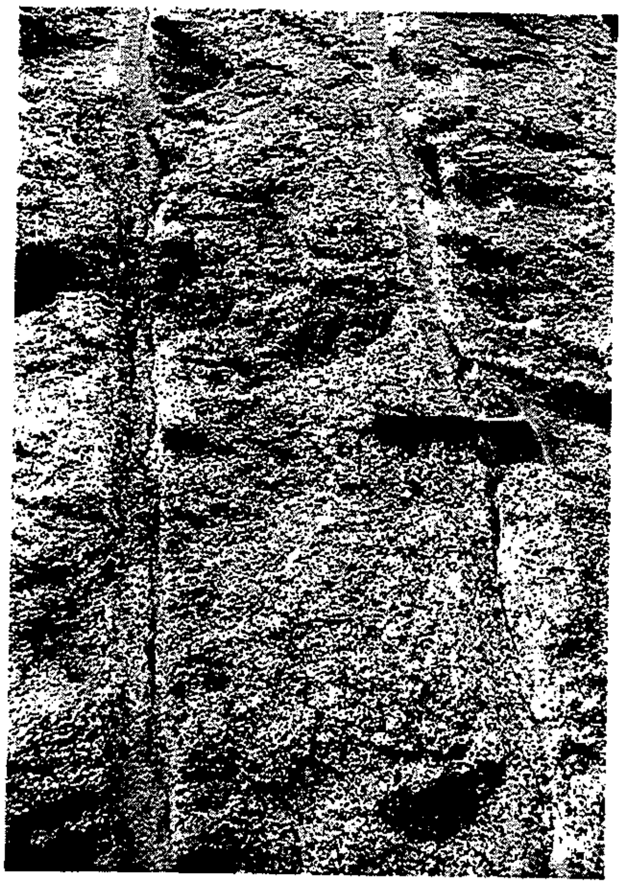


Plate 2 - Fracturing of presplit borings in granitic rock

Plate 3 - Fracturing of presplit borings in metamorphic rock

Plate 4 - Appearance of cut slope

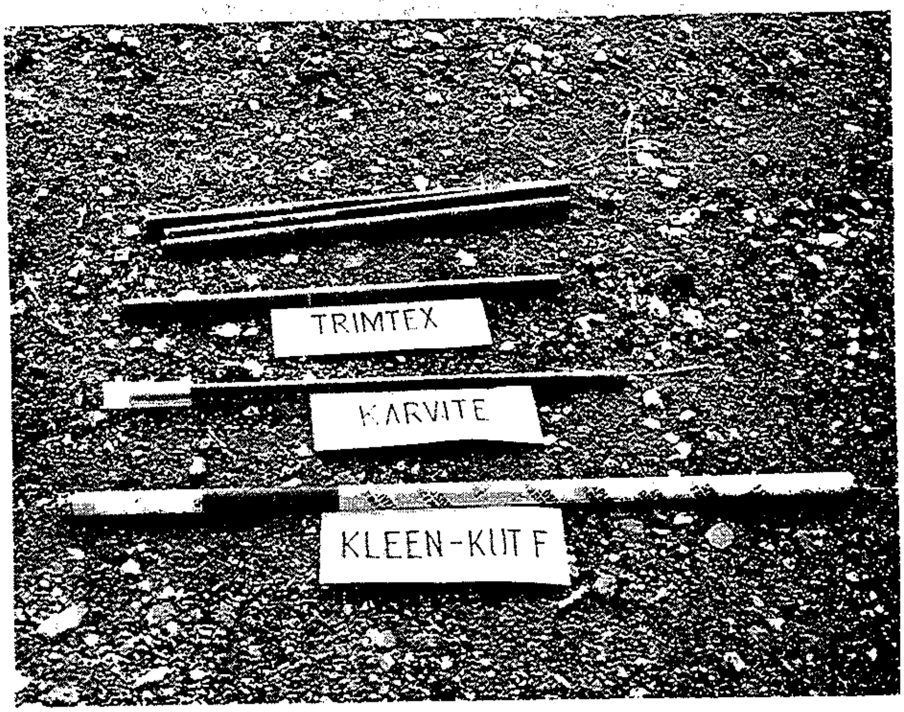


Plate 5 - Explosives

Plate 6 - Trimtex with s iral wrapped primacord

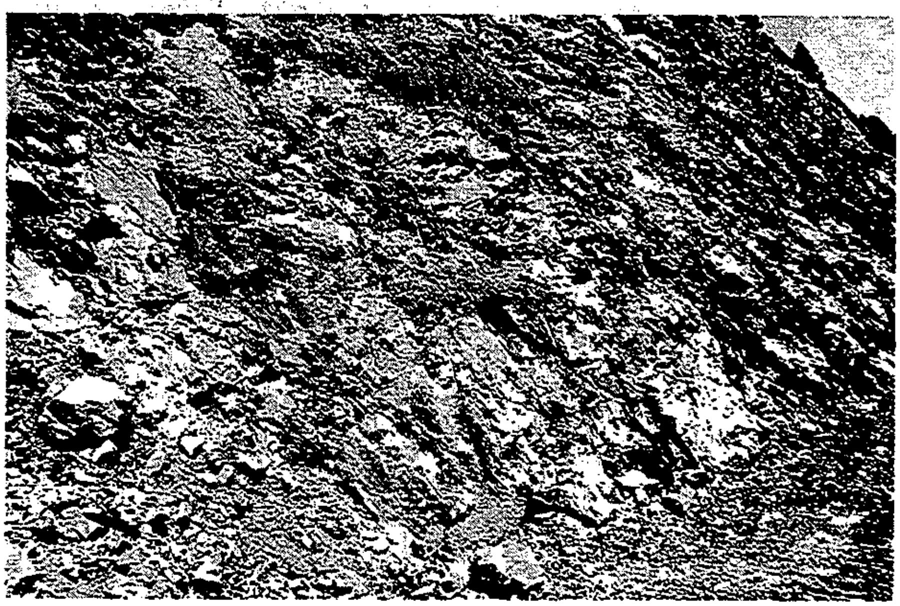


Plate 7 - Appearance of test slope before scaling

Plate 8 - Trimtex boring with some weak fracturing

Plate 9

Kleen-Kut F

Plate 10

Karvite

Plate 11

Trimtex wrapped
with primacord